New Tools Supporting New Learning Partnerships: Technology Development for GK-12

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Abstract: Twenty-first century technologies are enabling new kinds of collaboration between university-based scientists and K-12 science teachers, while also providing researchers with new windows on cross-institutional collaborative activity. This paper describes how innovative computer resources support a research project sponsored by the National Science Foundation that involves graduate teaching fellows in K-12 education programs.

Introduction

Rapid changes in technology are putting ever-greater strains on schools and teachers to provide relevant education for an uncertain future. At the same time, new technologies offer the potential for transforming teaching and learning in far-reaching ways by supporting new kinds of educational communities (Riel 2000, Roberts 2000). Twenty-first century technologies are enabling new kinds of collaboration between university-based scientists and K-12 science teachers, while also providing researchers with new windows on cross-institutional collaborative activity. This paper describes how innovative computer resources support a research project sponsored by the National Science Foundation (NSF) that involves graduate teaching fellows in K-12 education programs. The University of Illinois at Urbana-Champaign (UIUC) is one of more than 100 sites around the United States which were awarded three-year NSF funding for GK-12 projects beginning in 1999, 2000, 2002 or 2003 (National Science Foundation 2003). Now in its third year, the UIUC GK-12 program (http://gk12.ncsa.uiuc.edu) supports six graduate student fellows, each of whom partners with a faculty mentor and a high school teacher to integrate the use of computer-based modeling and scientific visualization in science and mathematics education. The school sites are located around Illinois, and so various computer technologies have become an important means of connecting fellows, mentors, teachers, and high school students.

Modeling and visualization software for the fields of chemistry and biology helps to connect high school learners with the kinds of real scholarly inquiry practiced daily by professional scientists. Custom software for scaffolding inquiry learning helps the **t**eams develop classroom lesson topics and connect distributed communities of learners. Web-delivered surveys capture self-report data about the participants experiences at the beginning, middle, and end of the year, and fellows submit entries to an online learning log at least once every two weeks. We are finding that these tools not only serve to archive data about participants' experiences but also help the participants to structure their own experiences, by giving them occasion to reflect on their own developing practice. We are exploring the potential for this emerging suite of software to serve as a toolkit for other cross-institutional technology partnerships.

Tools for Scientific Modeling and Visualization

UIUC GK-12 fellows and their partnering science teachers are making effective use of the Biology Student Workbench (http://peptide.ncsa.uiuc.edu), a simplified interface to a suite of computational biology database and visualization tools used by professional molecular biologists. The Biology Workbench (http://workbench.sdsc.edu) is a web-based computational environment that allows biologists to search many popular protein and nucleic acid sequence databases. The Biology Student Workbench provides an introduction to the use of the Biology Workbench for learning and teaching biology at all levels.

One fellow-teacher team in a Chicago-area high school has used Biology Student Workbench with freshman-level biology classes to learn about DNA sequencing (Gabric and Moore, undated). In this set of lessons, students first studied background information from the Human Genome Project (http://www.ornl.gov/hgmis/project/about.html) and from a public television program about DNA sequencing. They then attempted to interpret an electropherogram printout of a DNA sequence, obtained from a scientist at the Argonne National Laboratories. To determine what the printed-out sequence actually coded for, they used the Biology Student Workbench. Through this set of lessons, the students gained a better understanding of the Human Genome Project, learned how DNA is sequenced by scientists, and read a DNA sequence and determined the protein that it most likely coded for. Using the Biology Student Workbench in this way provides students with a different view of what research biologists actually do than is typical in high school classrooms.

Other UIUC GK-12 participants have found high-end scientific modeling and visualization software to be very useful for introducing physics and chemistry students to research areas involving complex mathematics or prohibitively expensive experimental equipment. Two commercial programs that fellows have used successfully for these purposes are Stella (http://www.hps-inc.com/Education/new_Stella.htm)
and Maya (http://www.alias.com/eng/products-services/maya/). Stella allows users to determine the probability of events in multiple runs of an experiment, by visually constructing equations that control relationships between various factors of interest. In the field of epidemiology, for instance, it can be used to chart the spread of an infection through a population, based on factors such as population size, time, rate of contagion, and rate of recovery. Physical principles such as rate of acceleration can also be modeled readily in Stella. One GK-12 teacher and fellow are taking advantage of this capability for a hands-on lesson unit in which students first use run experiments using remote-controlled model cars and chart their results in a spreadsheet, and later use Stella to model the conditions that would be impossible to replicate in a high school setting, such as supersonic speeds or zero gravity. Two other fellow-teacher teams are preparing for their students to visit a Chicago-area supercomputing center where the students will have the opportunity to work with Maya, a high-end three-dimensional graphical design package used to create special effects for theatrical films like the *Lord of the Rings* trilogy. Physics and chemistry teams have also made effective use of numerous free Java applets accessible via the Internet, which enable users to manipulate proteins and other molecular structures by panning, zooming and rotating. One site to which the teams turn frequently is the National Center for Biotechnology Information (www.ncbi.nim.nih.gov). NCBI offers numerous applets as well as the BLAST search tool, which affords rapid searching of nucleotide and protein databases.

UIUC GK-12 fellows familiarize themselves with the capabilities and features of available computer software for their fields, and work closely with their cooperating teachers and classes to identify the most appropriate technologies for their situations before putting them into use. One 2001-2002 fellow who documented her experience in detail (Kruse, undated) describes a four-step process of observing classes, developing curricular materials, integrating recommendations of the classroom teacher and faculty mentor, and evaluating both the use of the technologies in lessons and the impact of collaborative dynamics between fellows, teachers, mentors, and high school students. Her lesson plans for first-year chemistry were tied closely to the textbook-based curriculum and incorporated multiple technologies for molecular visualization. These included graphing calculators and probes, and a dozen free software programs: ChemViz (http://chemviz.ncsa.uiuc.edu/), eChem (http://hi-ce.eecs.umich.edu/sciencelaboratory/echem/), CHIME/RasMol (http://www.mdlchime.com/chime/), MathMol (http://www.nyu.edu/pages/mathmol), Web-based Chemical Investigations (http://www.paccd.cc.ca.us/instadmn/physcidv/chem_dp/htm/vweb.htm),
Simple Molecule Dynamics (http://cps-www.bu.edu/), Investigation Station (http://hi-ce.eecs.umich.edu/sciencelaboratory/index.html), 3-D Periodic Table of Atomic Radii
(http://www.wsu.edu/~wherland/#Radii), Virtual Chemistry (http://neon.chem.ox.ac.uk/vrchemistry/), IUMSC Common Molecules (http://www.recipnet.indiana.edu/common/common.html), WebElements (http://www.webelements.com/), Crystal Lattice Structures
(http://cst-www.nrl.navy.mil/lattice/mainpage.html), ChemBalancer (http://www.dun.org/sulan/chembalancer/), and ChemPuter (http://www.shef.ac.uk/chemistry/chemputer/). She also made use of six commercial software programs: Stella, CACHe (http://www.cachesoftware.com/), Spartan (http://www.wavefun.com/software/software.html), Mathematica (http://www.wolfram.com/products/mathematica/), Fundamentals of Chemistry (http://chem.myclass.net/Pages/fundamentals.cfm), and Riverdeep Chemistry Gateway and Chemistry Exploration (http://www.riverdeep.net/index.jhtml).

Tools for Scaffolding Inquiry Learning

Two free, web-accessible resources from the College of Library and Information Sciences at the University of Illinois provide supporting mechanisms for inquiry learning. The first of these is the Inquiry Page (http://inquiry.uiuc.edu), which enables users to archive and share information online, in the form of "inquiry units." Units are constructed by filling in a form with separate space for the various phases of inquiry learning: ask, investigate, create, discuss, and reflect. The creator of an inquiry unit may choose whether to share it with all visitors to the site or with specific users, or to keep it private. A search feature allows site visitors to find inquiries on topics that interest them. As of January 11, 2004, there were 17 public and 3 private inquiry units dealing with GK-12 at the Inquiry Page. Among the 17 publicly accessible units were a participating teacher's in-depth plan for a series of lessons involving use of Biology Student Workbench and the Human Genome Project (Gabric and Moore, undated), a 2001-2002 fellow's account of how she and her partnering teacher incorporated computer

visualization into molecular biology lessons (Kruse, undated), and several units created by members of the GK-12 evaluation team.

In mid-2003, Inquiry Page developers opened the Community Inquiry Laboratory (CIL) site (http://inquiry.uiuc.edu/cil), which allows users to create feature-rich websites by filling in web forms. A CIL may be used as a repository for one or multiple inquiry units, and it can also include other features such as a Discussion Forum, a Timeline, an annotated list of Web Links, and a Document Center where files may be uploaded for storage. As with the Inquiry Page, the author(s) of a CIL can choose whether each type of information or file within that CIL may be shared with the public or with a specific set of users, or is to remain private. The CIL resource was built with and runs on the open-source software combination known as "LAMP" (Linux, Apache, MySQL, PHP) and incorporates as features a number of open-source applications created by other developers. As the CIL platform matures, its developers are exploring the feasibility of making it available as an open-source package as well. In the semester since the Community Inquiry Laboratory website went online, several GK-12-related CILs have been created. The evaluation team uses a limited-access CIL as a repository for various in-progress works, and fellows and teachers have created additional CILs for use with their students.

Tools to Support Evaluation and Reflection

Timely and effective communication among fellows, teachers, mentors, and the evaluation team is critical to the success of the GK-12 project. Two tools that help meet this need are web-delivered surveys and fellows' learning logs. At the beginning, middle, and end of the academic year, project participants are asked to complete surveys that address the project as a whole, the fellow's own site, teaching and learning at the site, the role of technology at the site, and the effects of GK-12 participation on the fellow's professional development. Twice each month, fellows are also expected to submit an entry to a learning log which is linked from the project website. Both the surveys and learning logs are protected by passwords and are accessible only to the individual who completes them and to members of the GK-12 evaluation team. Participants are assured that all information they provide via the surveys and logs is intended only for evaluating the project and partnerships generally, and will not be used to assess their individual performance.

Conclusion

The National Science Foundation-sponsored GK-12 projects, at the University of Illinois and elsewhere, represent a conscious attempt to foster partnerships between high school teachers and young scientists, and to prepare a new generation of scholar-educators in the sciences. New web-delivered technologies are proving to be an invaluable element in these partnerships, in the areas described in this paper. First, the same modeling and visualization software used by scientists can serve as a scaffold to acquaint high school learners with the latest and most essential scientific knowledge. Second, resources like the Inquiry Page and Community Information Lab websites can support advanced knowledge construction by individual learners, teacher-fellow teams, whole classes, and larger communities of learners. In addition, online surveys and learner logs can provide a means of communication between GK-12 participants and project evaluators. Table 1, below, summarizes the tools and uses discussed in this paper.

Name	Description	Usefulness to UIUC GK-12 Partnerships
Biology Student Workbench (free)	Student interface to a web-based computational environment that allows biologists to search many popular protein and nucleic acid sequence databases.	Modeling / visualization
Stella (commercial)	Allows users to determine the probability of events in multiple runs of an experiment.	Modeling / visualization
Maya (commercial)	A three-dimensional graphical design package.	Modeling / visualization
NCBI applets (free)	Applets enable users to manipulate proteins and other molecular structures by panning, zooming and rotating.	Modeling / visualization
ChemViz (free)	An interactive chemistry program which incorporates computational chemistry simulations and visualizations for use in the chemistry classroom.	Modeling / visualization
Inquiry Page (free)	A dynamic virtual community where inquiry-based education can be discussed, resources and experiences shared, and innovative approaches explored in a collaborative environment.	Inquiry learning
Community Inquiry Laboratory (free)	Feature-rich websites, built via web forms, which support communities of users in developing shared resources and working on common problems.	Inquiry learning
Web-delivered surveys (in-house)	Password-protected survey forms enable members of UIUC GK-12 community to enter responses online to limited-choice and open-ended items in beginning-of-year, mid-year, and end-of-year surveys prepared by the Evaluation Team.	Evaluation / reflection
Web-based learning logs (in-house)	Password-protected web log resource provided for UIUC GK-12 Fellows to enter reflections and notes about their teaching on a bi-weekly basis.	Evaluation / reflection

Table 1. Software tools used by UIUC GK-12 Partners.

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